

Pacific Northwest National Laboratory (PNNL) with support from the Defense Threat Reduction Agency (DTRA) Nuclear Arms Control Technology (NACT) Program is developing tools to analyze SOH data reported from noble gas systems within the International Monitoring System (IMS) network. The current version of the tool was tested against the Swedish Automated Unattended Noble Gas Analyzer (SAUNA) and the PNNL-developed Xenon International system. The SOH tool uses a modular framework where IMS2.0 formatted SOH data is first written to a database. An auto analysis daemon executes different algorithms, in parallel, on the data as it is received and stores the results in the database. The station dashboard page uses these results to update the station health. The graphical user interface (GUI) is web-based and used to interact with the data. PNNL is collaborating closely with the U.S. IMS radionuclide station operator, General Dynamics (GD), for feedback and testing of the tool. The tool, implementation framework, and current status are presented here.

Goals and Objectives

Challenge

Data availability from IMS stations is required to be at 95% or better (no more than 15 days of downtime per year). This can be a challenge when systems have failures that require unscheduled maintenance visits. Analysis of SOH data can provide a better understanding of current and future potential failures.

Research Goals

Analysis of SOH data verifies that systems are running within specification and aids in post-run diagnostics. The goals of this research are:

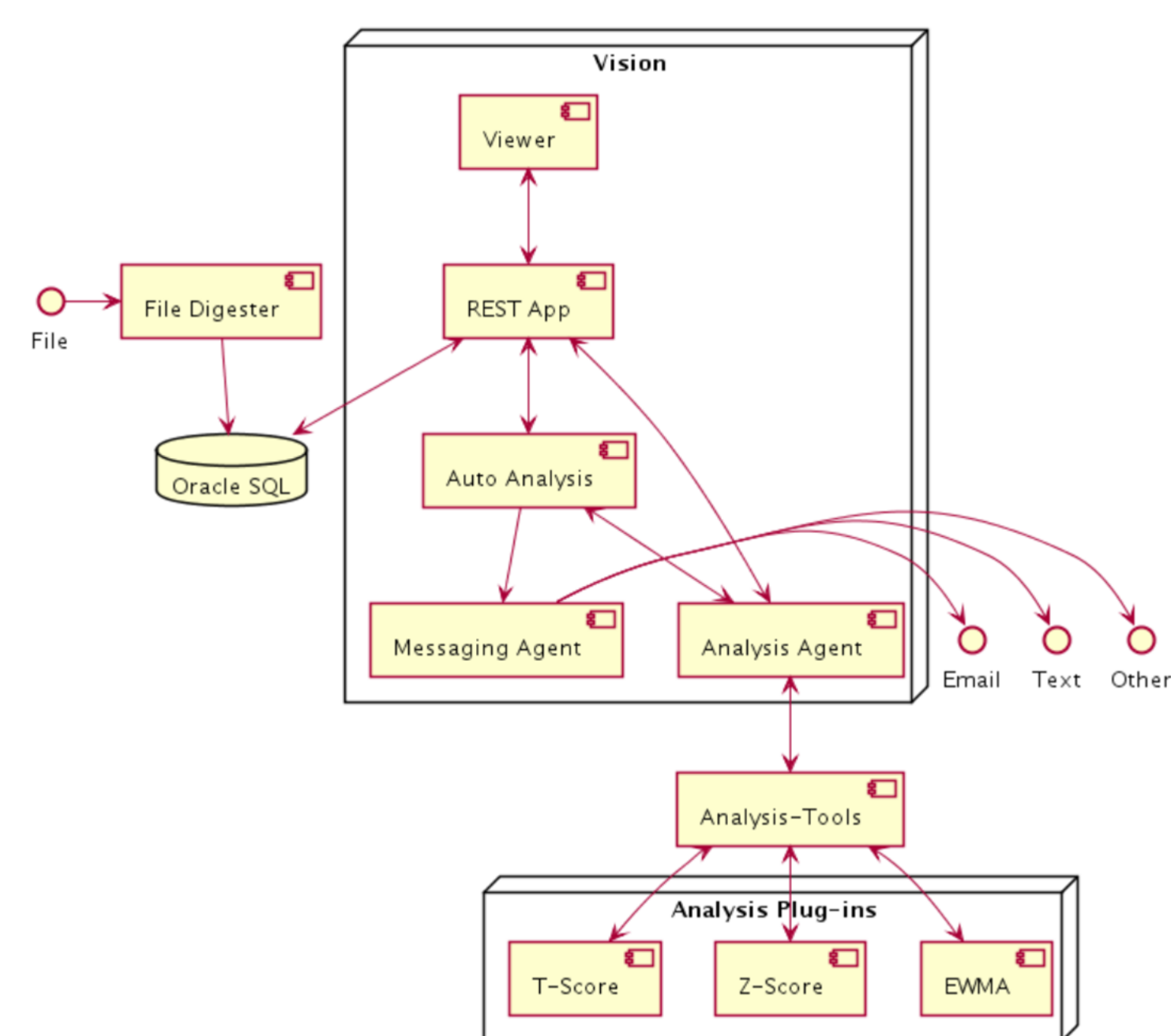
- ▶ Identify current and potential future failures through SOH analysis
- ▶ Increase system uptime
- ▶ Increase data availability
- ▶ Recognize and fix problems early
- ▶ Reduce false-positives
- ▶ Identify sensor trends

Methods

Implementation

A modular software analysis framework was designed and implemented.

- ▶ Standard interface for analysis algorithms
- ▶ Standard interface for data sources (IMS2.0)
- ▶ Web-based graphical user interface
- ▶ Software developed in Java



This figure illustrates the architecture of the SOH analysis as IMS2.0 formatted SOH data is received.

Alerting Algorithms

Algorithms implemented for testing are outlined below and are currently being tested against multiple stations.

- ▶ Simple per sensor limits based algorithm
 - Uses pre-defined limits per sensor per time period within the cycle to generate a warning, critical, or fatal alert.
- ▶ Exponential Weighted Moving Average (EWMA¹)
 - Does not require a training set
 - The model is less influenced by data that is further removed in time (weights decrease as observations get older)
 - Robust against normal and non-normally distributed data²

$$Z_t = \alpha Y_t + (1 - \alpha)Z_{t-1}, \quad 0 < \alpha \leq 1$$

Z_t = new model value
 Z_{t-1} = previous model value
 Y_t = new observation
 α = weighting factor
 t = time (minute in 1440 time in the case of SAUNA)

Trend Analysis

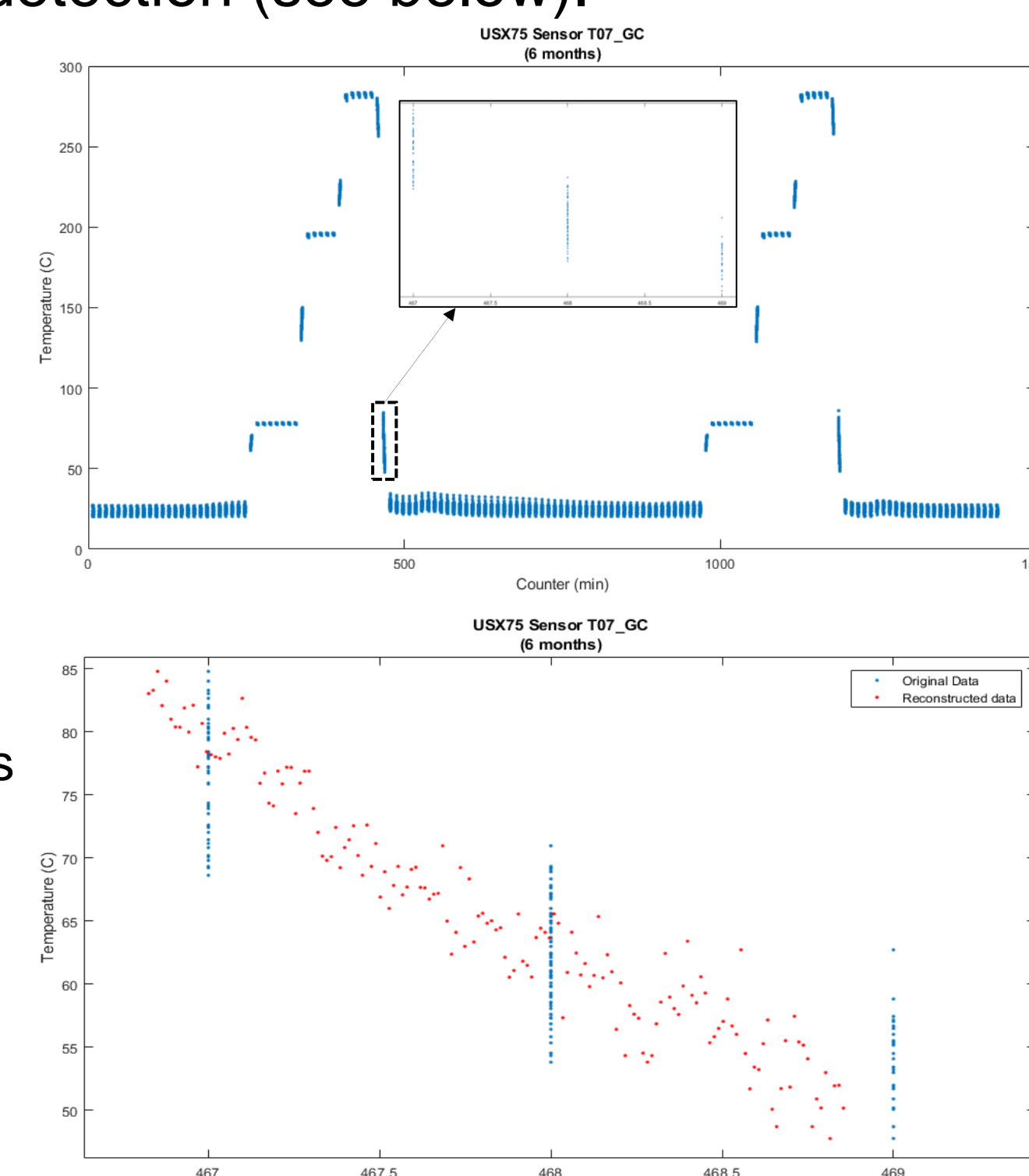
Trend identification and quantification algorithms are currently being assessed. These include, analysis of positive or negative change³ over time using Savitzky-Golay filtering⁴, Pearson Correlation⁵, Kendall's Rank⁶, linear regression, and Theil-Sen regression⁷.

Analysis Challenges

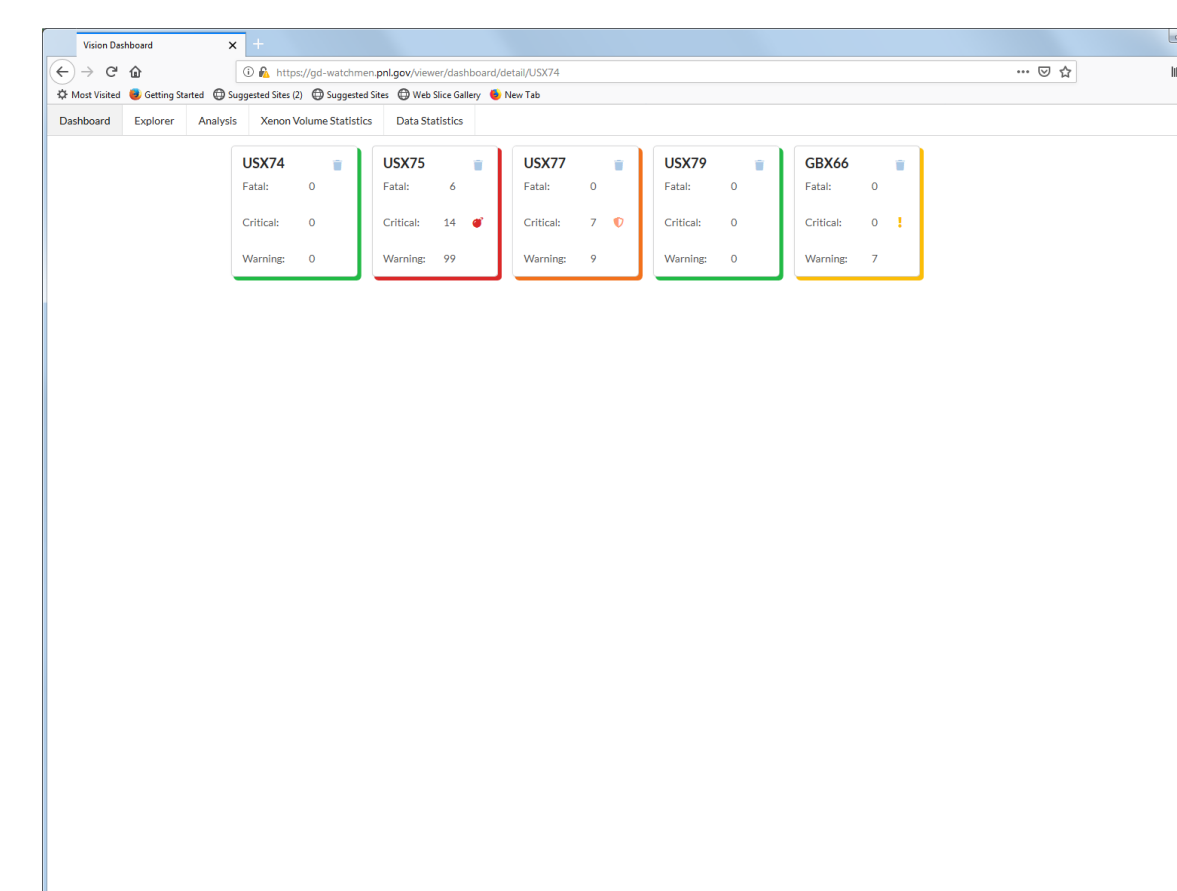
- ▶ Stations that do not report a system counter makes it difficult to know where in the cycle the system is. A mitigation strategy was developed in conjunction with GD.
- ▶ Sampling point changes relative to cycle time over long periods presents challenges for trend detection (see below).

Station USX75 sensor T07_GC graphed for nearly a six month time period. When a small range is zoomed in, it appears that the sampling point changes slowly, eventually jumping to the next minute.

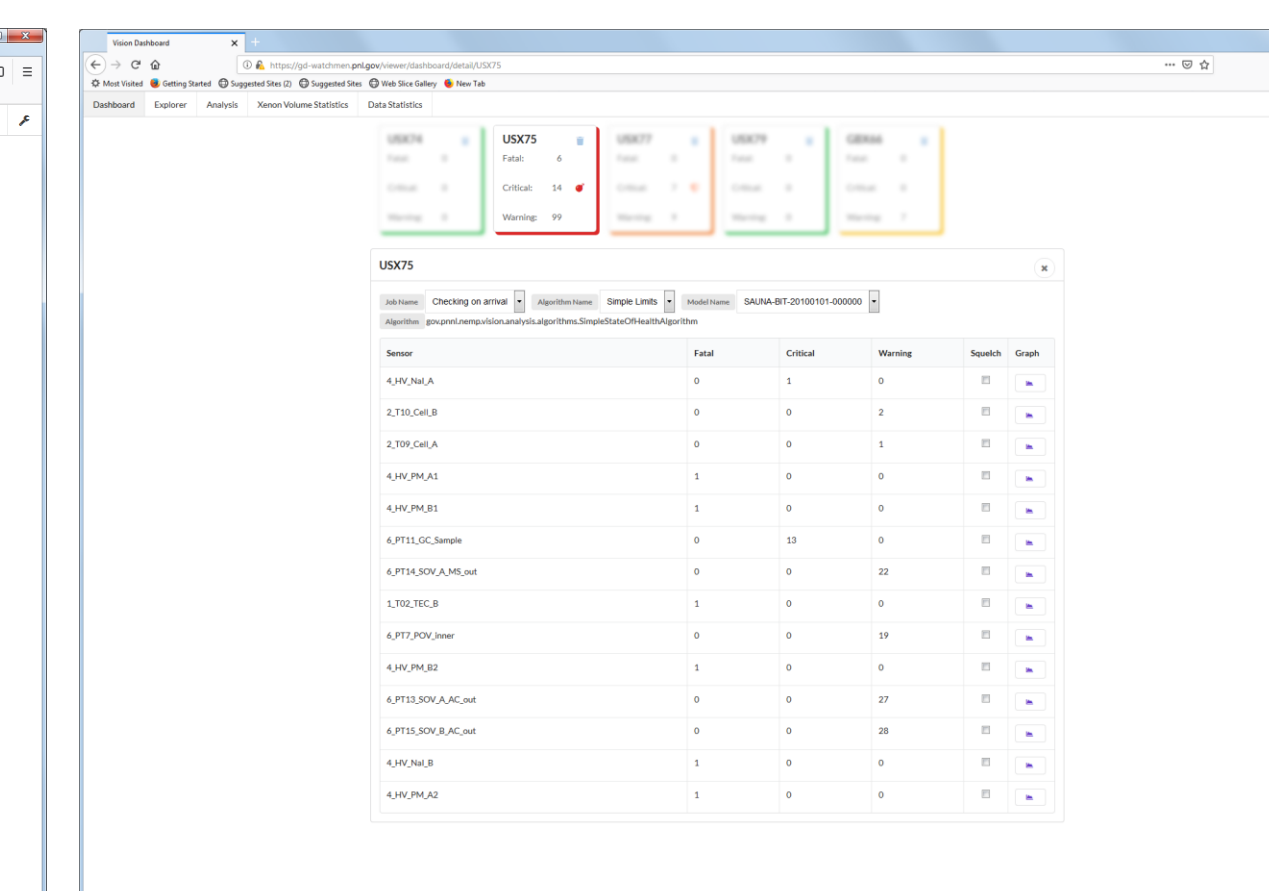
The change appears to be ~0.80 seconds per cycle. If we reconstruct the counter time with this offset, the data appears to follow the normal sensor behavior and illustrates a sampling drift relative to the cycle.



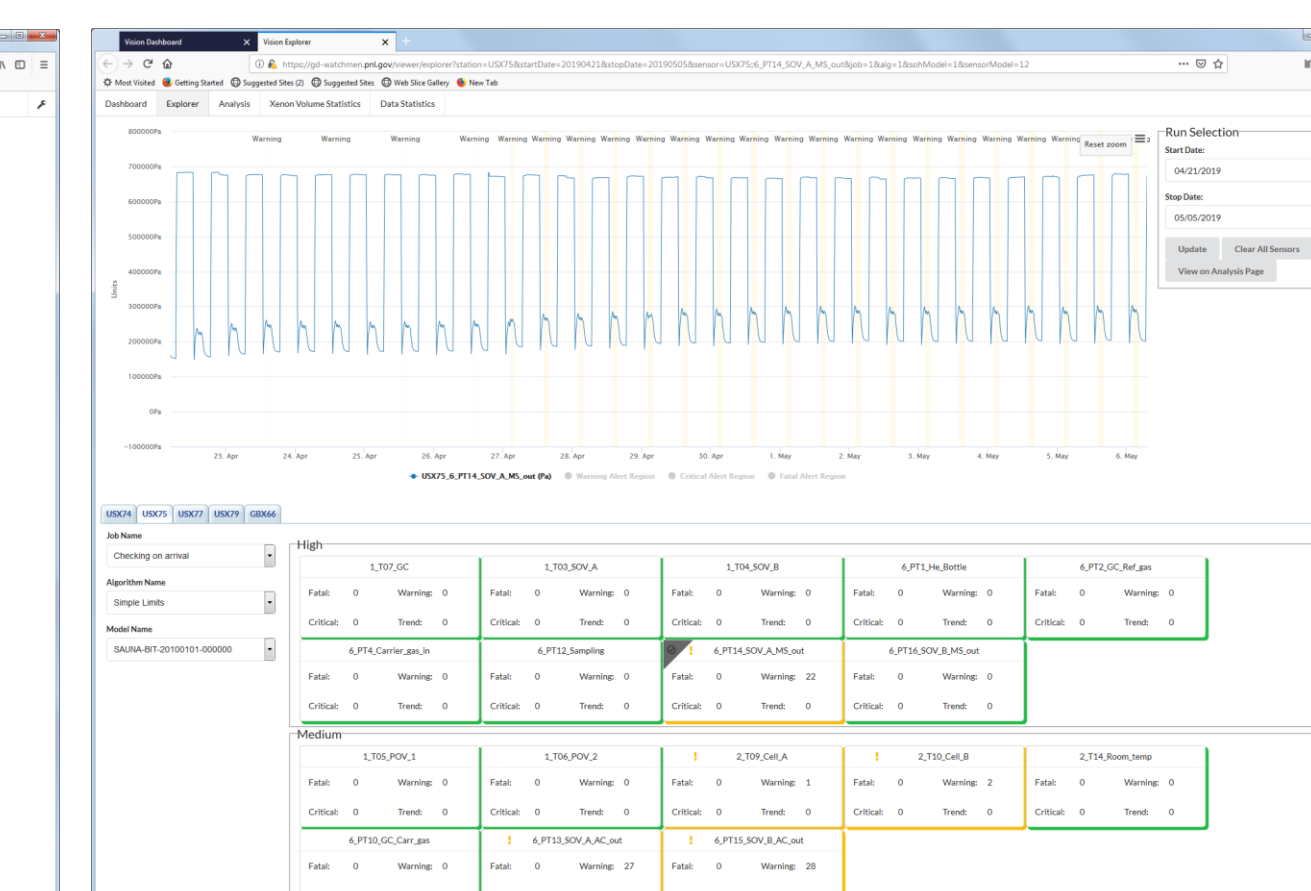
Outputs



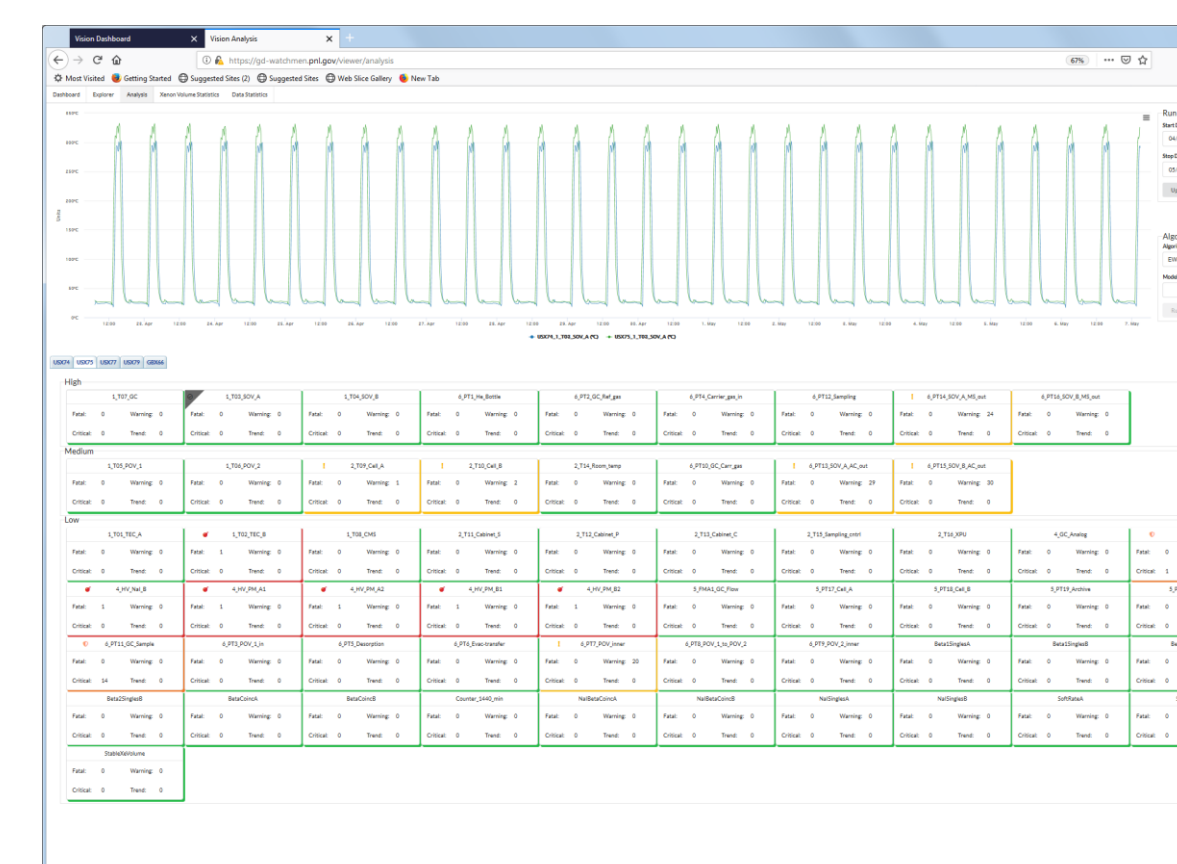
The Station Dashboard page displays the status of all stations currently defined.



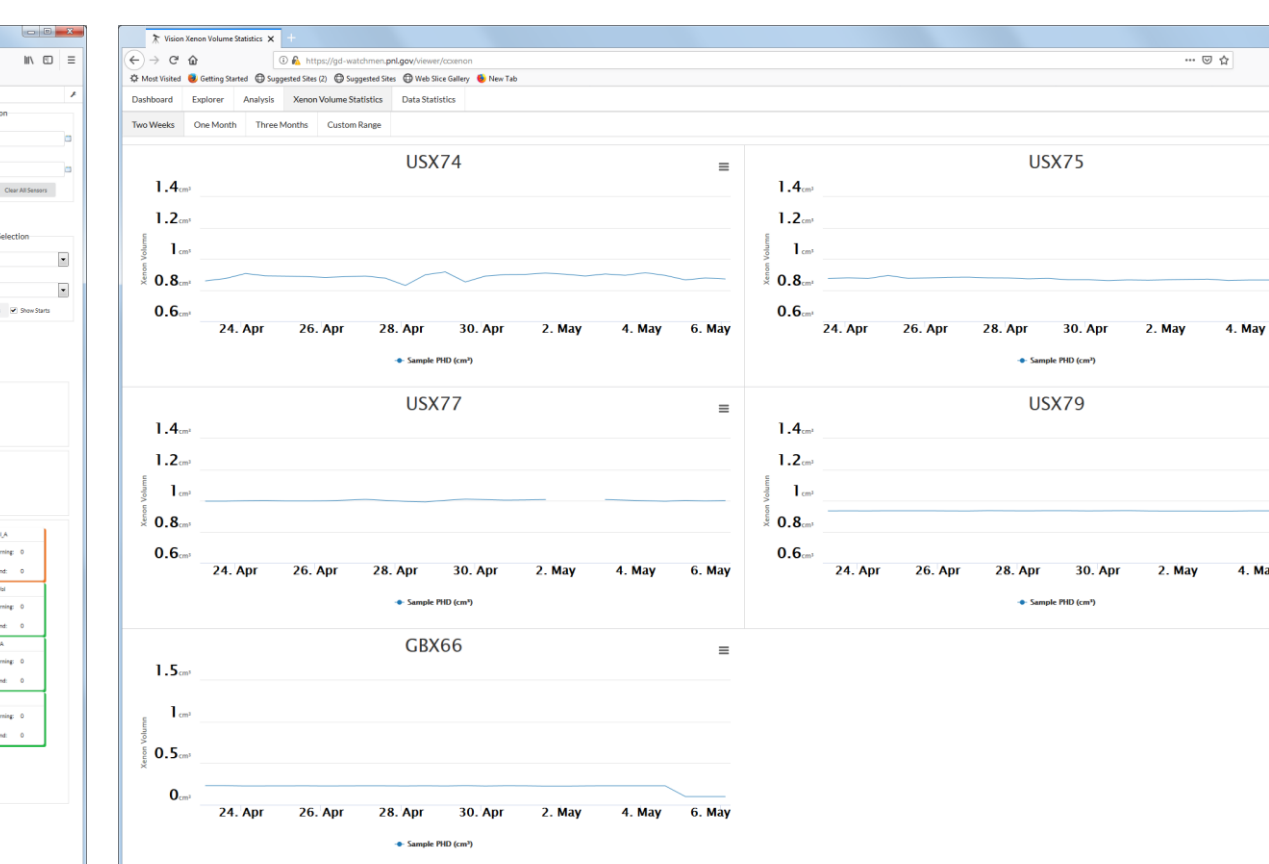
When a station is selected, the sensors causing the alerts are displayed (USX75 was selected here as an example)



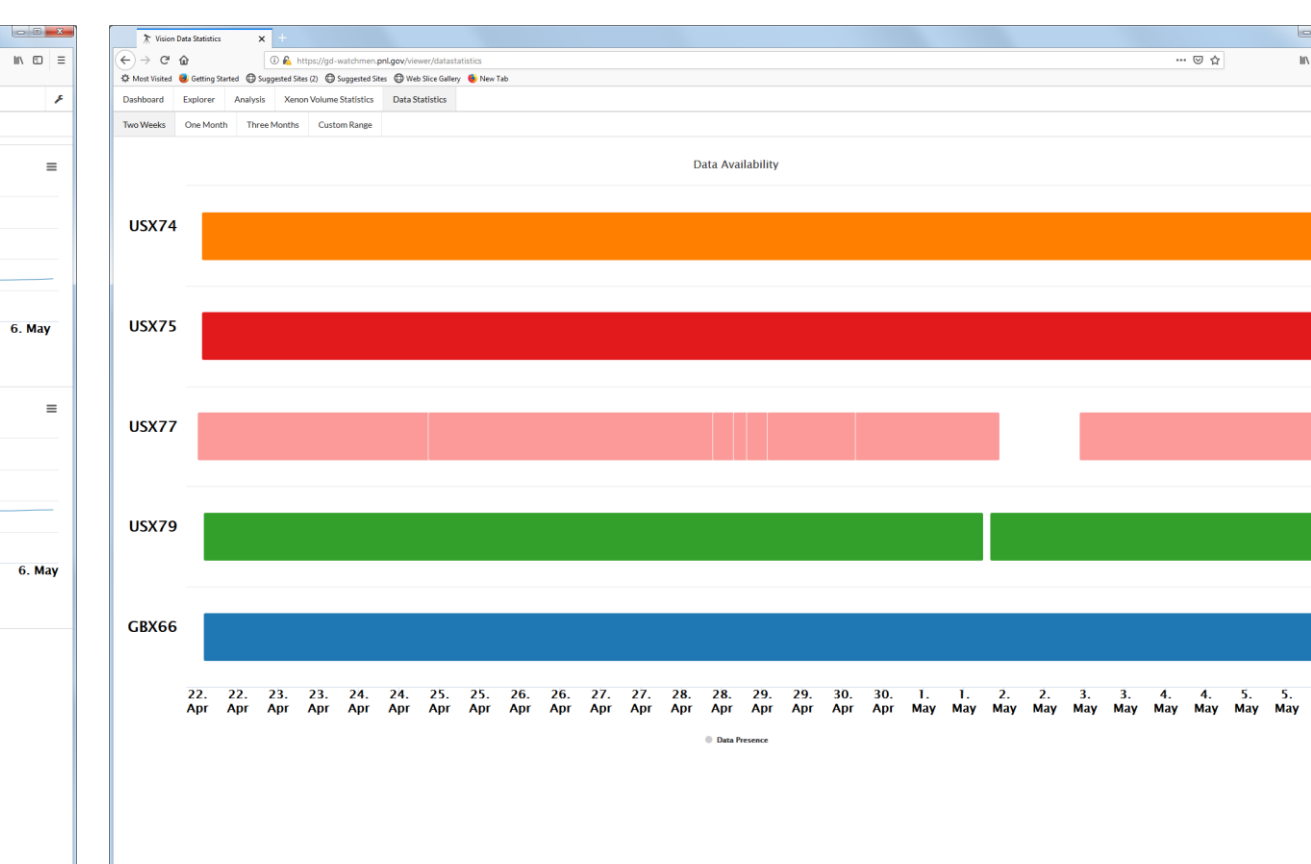
Selecting the graph icon for a sensor brings up the sensor in another page already graphed and indicates when the alert occurred.



The analysis page provides the ability to manually run algorithms on the data and, for instance, plot a single sensor from multiple stations.



This page shows xenon volumes for selected stations for a customizable duration (the past two weeks is displayed in the example)



This page shows the data availability for selected stations for a customizable duration (the past two weeks is displayed in the example)

Conclusion

PNNL, working in collaboration with GD, developed a tool for analyzing SOH data from noble gas systems, such as the SAUNA. The tool was designed to use multiple algorithms and analyze SOH data using IMS2.0 format. The tool was tested against SAUNA data and preliminarily tested against SOH data from Xenon International. PNNL is currently testing the tool with GD and developing a plan to extend it to Radionuclide Aerosol Sampler/Analyzer (RASA) systems.

References

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- ²Montgomery, Douglas (2005) "Introduction to Statistical Quality Control"
- ³Lloyd S. Nelson, "Technical Aids," Journal of Quality Technology 16, no. 4 (October 1984), 238-239.
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- ⁷Akritis, Michael G.; Murphy, Susan A.; LaValley, Michael P. (1995), "The Theil-Sen estimator with doubly censored data and applications to astronomy", Journal of the American Statistical Association

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